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NEW Product

SIL30C Single

Application Note 132

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ARTESYN® TECHNOLOGIES

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- **Wide trim range (0.9V to 5.0V)**
- **High power density design means reduced board space requirement**
- **Remote sense**
- **Power good output signal (open collector)**
- **Operating ambient temperature 0ºC to 80ºC**
- **Over-temperature protection**
- **Optional current share**
- **Horizontal and vertical models available**

1. Introduction

This application note describes the features and functions of Artesyn Technologies' SIL30C series of high power density adjustable output DC/DC converters. These open-frame, 30A output modules are available in both vertical and horizontal versions and are designed for use in workstation, computing, industrial and communication applications. The SIL series offers great flexibility in board level power distribution by means of its wide output voltage range and small package when compared to standard brick solutions.

2. Models

The SIL series comprises 1 model, as listed in Table 1 .

Model	Input Voltage	Output Voltage	Output Current
*SIL30C-12SADJ-V	10.2 - 13.8VDC	0.9 - 5.0V	30A

*The standard unit with the suffix '-V' is for vertical mounting. To order a unit with horizontal mounting, please add the suffix '-H' to the model number, e.g. SIL30C-12SADJ-H.

Table 1 - Available SIL30C Models

Features

- Wide trim range (0.9V to 5.0V)
- Horizontal and vertical models available
- High power density design means reduced board space requirement
- Remote sense
- Power good output signal (open collector)
- Operating ambient temperature 0ºC to 80ºC
- Remote ON/OFF (active high)
- Over-temperature protection
- 0A minimum load
- Input undervoltage lockout
- Over-current and short-circuit protection
- Optional current share

3. General Description

3.1 Electrical Description

The SIL30C is implemented using a voltage-mode two-phase Buck/Boost topology. A block diagram of the converter is shown in Figure 1.

The output is adjustable over a range of 0.9V to 5.0V by using a resistor from the trim pin to ground or by driving the TRIM pin with a voltage. The remote sense feature is able to make up for 400mV drop from the output of the converter to where the sense lines are connected too.

The converter can be shut down via a remote on/off. This input is run with positive logic that is compatible with popular logic devices. Positive logic implies that the converter is enabled if the remote on/off input is high (or floating), and disabled if it is low.

The power good signal is an open collector output that is pulled low by the pwm controller when it detects the output is not within ±10% of its set value.

The output is monitored for overcurrent and short circuit conditions. The current flow is monitored through each output inductor and when the pwm controller detects an overcurrent condition it folds back the output.

The converter is also protected against over temperature conditions. If the converter is overloaded or the ambient temperature gets too high, the converter will shut down until the temperature falls below a minimum threshold. There is a thermal hysteresis of typically 10ºC, to protect the unit.

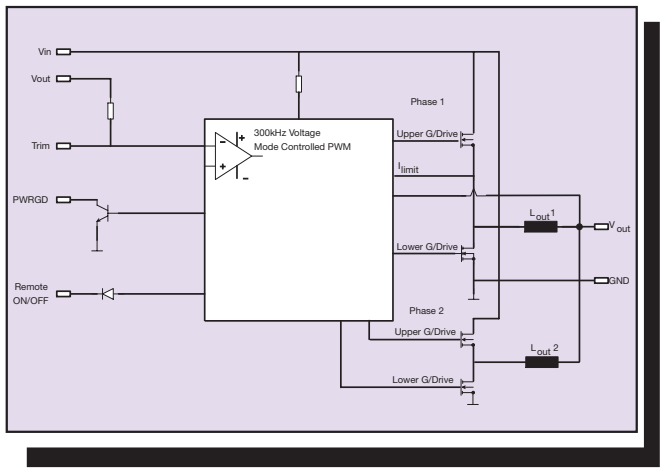


Figure 1 - Electrical Block Diagram

3.2 Physical Construction

The SIL30C is constructed using a multi-layer FR4 PCB. SMT power components are placed on one side of the PCB, and all low-power control components are placed on the other side. Heat dissipation of the power components is optimized, ensuring that control components are not thermally stressed.

The converter is an open-frame product and has no case or case pin. The open-frame design has several advantages over encapsulated closed devices. Among these advantages are:

• Cost: no potting compound, case or associated process costs involved
• Thermals: the heat is removed from the heat generating components without heating more sensitive, less tolerant

components such as opto-couplers
• Environmental: some encapsulants are not kind to the environment and create problems in incinerators. Further more open-frame converters are more easily re-cycled
• Reliability: open-frame modules are more reliable for a number of reasons, including improved thermal performance and reduced TCE stresses.

A separate paper discussing the benefits of open-frame DC/DC converters (Design Note 102) is available at www.artesyn.com

4. Features and Functions

4.1 Wide Operating Temperature Range
The SIL's ability to accommodate a wide range of ambient temperatures is the result of its extremely high power conversion efficiency and resultant low power dissipation, combined with the excellent thermal performance of the PCB substrate. The maximum output power that the module can deliver depends on a number of parameters, primarily:

• Input voltage range
• Output load current
• Air velocity (forced or natural convection)
• Mounting orientation of target application PCB, i.e. vertical/horizontal mount, or mechanically tied down (especially important in natural convection conditions)
• Target application PCB design, especially ground planes. These can be effective heatsinks for the converter.

The SIL30C modules have a nominal operating temperature range of 0 to 50ºC but this can be extended to 80ºC if suitable de-rating and/or forced air cooling is used. A number of de-rating curves for each model at several output voltage setpoints are included in the long form data sheet for that model. Thermal performance is discussed further in Section 7.2.

4.2 Output Voltage Adjustment
The output voltage on all models is adjustable from 0.9V to 5.0V. Details on how to trim all models are provided in Section 7.3

4.3 Undervoltage Lockout
The modules in this line have built in undervoltage lockout to ensure reliable output power. The lockout prevents the unit from operating when the input voltage is to low.

The SIL30C has an input range of 10.2V – 13.8V with UV lockout occurring between 8.0V to 8.6V. This allows more flexibility in designing and ensures operation on supply lines with large tolerances.

4.4 Current Limit and Short-Circuit Protection
All SIL30C models have a built-in foldback current limit function and full continuous short-circuit protection. The module monitors current through each output inductor of the converter. When overcurrent condition occurs, the module folds back the output voltage and current until the fault condition is removed.

Determining the overcurrent condition is dependent on the resistance of the inductor windings because the voltage drop across the inductor determines the overcurrent trip point. The inception point is typically 130% of rated full load at 25ºC. Ambient temperature influences the current limit inception point since resistance of copper rises with temperature.
Note that none of the module specifications is guaranteed when the unit is operated in an overcurrent condition. The unit will not be damaged in an overcurrent condition because it will be protected by the OTP function, but the converter's lifetime may be reduced.

4.5 Remote ON/OFF
The remote ON/OFF input allows external circuitry to put the SIL converter into a low dissipation sleep mode. Active-high remote on/off is available as standard.

Active-high units of the SIL series are turned on if the remote ON/OFF pin is high (or floating). Pulling the pin low will turn off the unit. To guarantee turn-on the enable voltage must be above 2.4V and to turn off the enable voltage must be pulled below 0.8V

Figures in the Long Form Data Sheet show the response of the unit to switching on and off the remote ON/OFF feature. The remote ON/OFF input can be driven in a variety of ways as shown in Figures 2, 3 and 4. If the remote ON/OFF signal originates on the primary side, the remote ON/OFF input can be driven through a discrete device (e.g. a bipolar signal transistor) or directly from a logic gate output. The output of the logic gate may be an open-collector (or open-drain) device. If the drive signal originates on the secondary side, the remote ON/OFF input can be isolated and driven through an optocoupler.

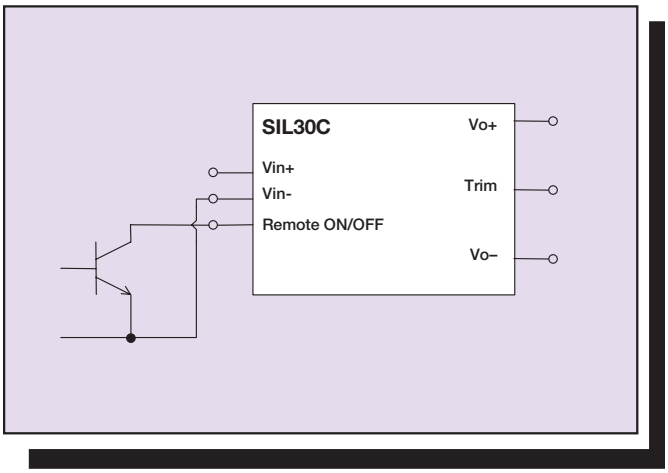


Figure 2 - Remote ON/OFF Input Drive Circuit for Non-Isolated Bipolar

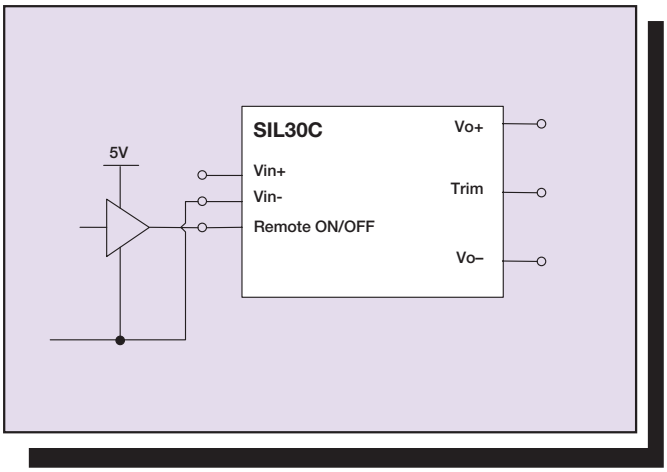


Figure 3 - Remote ON/OFF Input Drive Circuit for Logic Driver

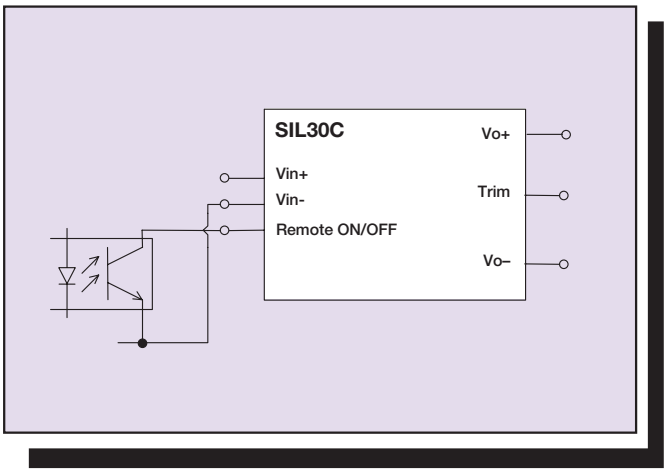


Figure 4 - Remote ON/OFF Input Drive Circuit using an Optocoupler to maintain the isolation barrier from primary to secondary

4.6 POWER GOOD Signal

The SIL30C modules have a power good indicator output. This output pin uses positive logic and is open collector. Also, the the power good output is able to sink 5mA.

When the output of the module is within ±10% of the nominal set point, the power good pin can be pulled high. Figures in the Long Form Data Sheet show how the power good signal behaves when the remote ON/OFF feature is used to turn the module on and off.

4.7 Over Temperature Protection (OTP)

The SIL30C is equipped with non-latching over-temperature protection. A temperature sensor monitors the temperature of the PCB near one the main FETS. If the temperature exceeds a threshold of 130°C (typical) the converter will shut down, disabling the output. When the substrate temperature has decreased by 10ºC the converter will automatically restart.

The converter might experience over-temperature conditions during a persistent overload on the output. Overload conditions can be caused by external faults. OTP might also be entered due to a loss of control of the environmental conditions (e.g. an increase in the converter's ambient temperature due to a failing fan).

5. Safety

5.1 Input Fusing

It is recommended the user provide a fuse in the input line. The amperage rating of the fuse will depend on the output voltage setpoint and the output current in the application. Please consult the factory for details.

6. Use in a Manufacturing Environment

6.1 Resistance to Solder Heat

The SIL series converters are intended for PCB mounting. Artesyn Technologies has determined how well the product can resist the temperatures associated with soldering of PTH components without affecting its performance or reliability. The method used to verify this is MIL-STD-202 method 210D. Within this method two test conditions were specified, Soldering Iron condition A and Wave Solder Condition C.

For the soldering iron test, the UUT was placed on a PCB with the recommended PCB layout pattern shown section 7. A soldering iron set to 350ºC ±10ºC was applied to each terminal for 5 seconds. The UUT was then removed from the test PCB and examined under a microscope for any reflow of the pin solder or physical change to the terminations. None was found.

For the wave solder test, the UUT was again mounted on a test PCB. The unit was wave soldered using the conditions shown in Table 2 . The UUT was inspected after soldering and no physical change was found on the pin terminations.

Temperature	Time	Temperature Ramp
260°C±5°C	10sec±1	Preheat 4°C/sec to 160°C. 25mm/sec rate

Table 2 - Wave Solder Test Conditions

6..2 Water Washing

Where possible, a no-clean solder paste system should be used for solder attaching the SIL product onto application boards. The SIL is suitable for water washing applications, because it does not have entrapment areas where water and residues may become trapped long term. However, the user must ensure that the drying process is sufficient to remove all water from the converter after washing - never power the converter unless it is fully dried. The user's process must clean the soldered assembly in accordance with ANSI/J-STD-001.

6.3 ESD Control

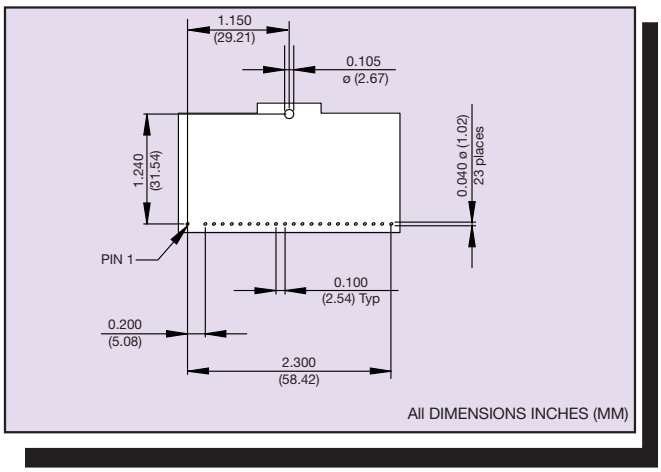
SIL units are manufactured in an ESD controlled environment and supplied in conductive packaging to prevent ESD damage occurring before or during shipping. It is essential that they are unpacked and handled using approved ESD control procedures. Failure to do so could affect the lifetime of the converter.

7. Applications

7.1 PCB Layout

The pin diagrams for the SIL30C are detailed in Figures 5a and 5b

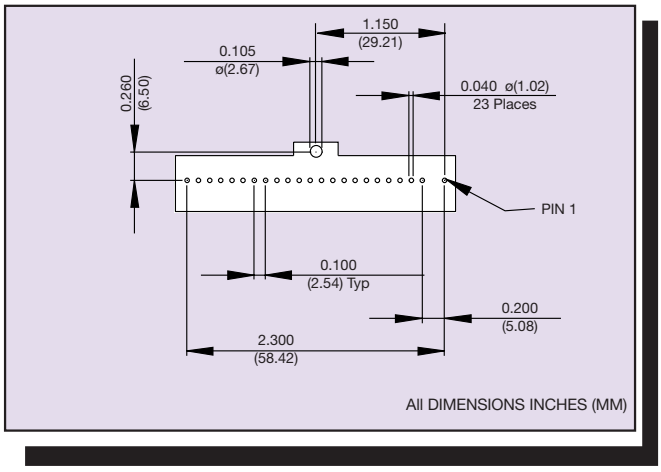
VIEW IS FROM TOP SIDE



THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

ALL DIMENSIONS IN INCHES (mm)
ALL TOLERANCES ARE ±0.004 (0.10)

Figure 5a - SIL30C-12SADJ-H Recommended Footprints



VIEW IS FROM TOP SIDE

THERMAL RELIEF IN CONDUCTOR PLANES
REFERENCE IPC-D-275 SECTION 5.3.2.3

ALL DIMENSIONS IN INCHES (mm)
ALL TOLERANCES ARE ±0.004 (0.10)

Figure 5b - SIL30C-12SADJ-V - Recommended Footprints

7.2 Thermal Performance

The electrical operating conditions of the SIL, namely:

- Input voltage, V_{in}
- Output voltage, V_o
- Output current, I_o

determine how much power is dissipated within the converter. The following parameters further influence the thermal stresses experienced by the converter:

- Ambient temperature
- Air velocity
- Thermal efficiency of the end system application
- Parts mounted on system PCB that may block airflow
- Real airflow characteristics at the converter location

In order to simplify the thermal design, a number of thermal derating plots are provided in the long form data sheet. Selected plots are repeated in Figures 6 and 7. These derating graphs show the load current of the SIL versus the ambient air temperature and forced air velocity. However, since the thermal performance is heavily dependent upon the final system application, the user needs to ensure the thermal reference point temperatures are kept within the recommended temperature rating. It is recommended that the thermal reference point temperatures are measured using a thermocouple or an IR camera. In order to comply with stringent Artesyn derating criteria the ambient temperature should never exceed 80°C. Please contact Artesyn Technologies for further support.

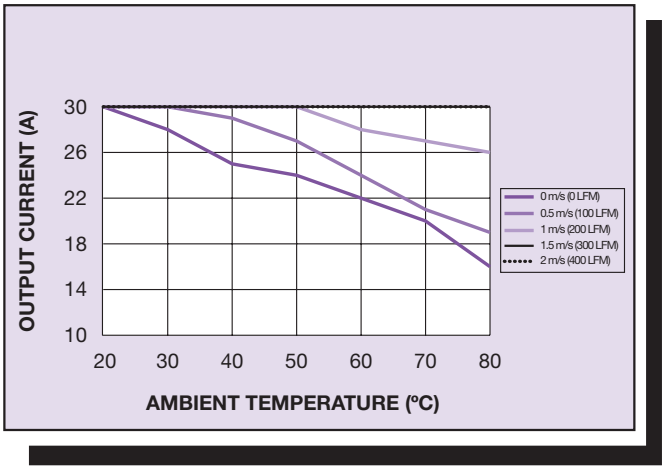


Figure 6 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL30C with Vout set to 2.5V

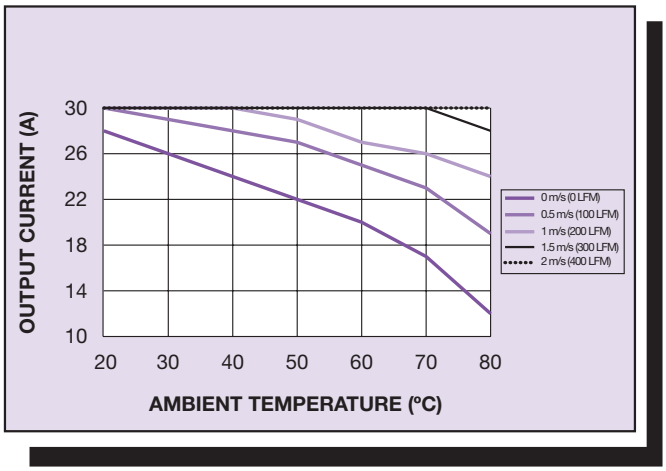


Figure 7 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL30C with Vout set to 5V

The maximum acceptable temperature measured at the thermal reference point is 100ºC. This is shown in figure 8

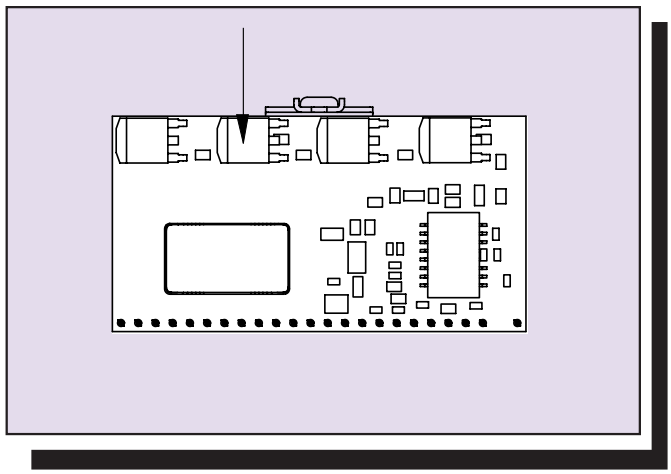


Figure 8 - Thermal Reference Point Location Converters

7.3 Output Voltage Adjustment

The output on the module is trimmable by connecting an external resistor between the TRIM pin and ground as per figure 9 or by driving the trim pin with a voltage per figure 11.

The SIL30C module has a trim range of 0.9V to 5.0V. A plot of trim behaviour is shown in Figure 10.

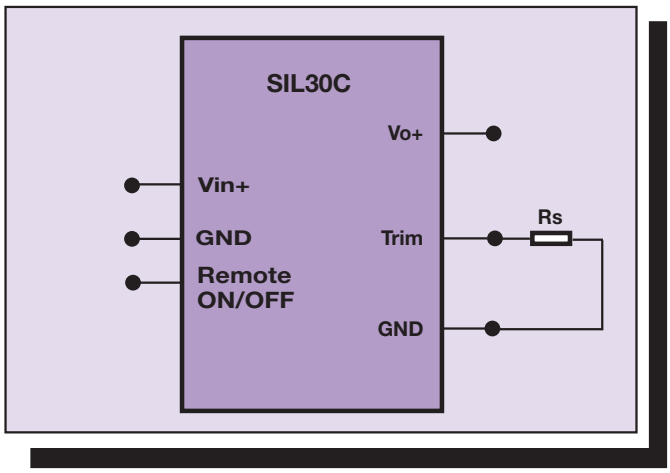


Figure 9 - Trimming Output Voltage

The resistor trim equation for the SIL is as follows:

$$\text{Rset (k}\Omega) = \frac{12.69 - \text{Vout}}{\text{Vout} - 0.9}$$

Where,
Vout is the required voltage setpoint
Rset is the resistance required between TRIM and ground Rset values should not be less than 1.8kΩ

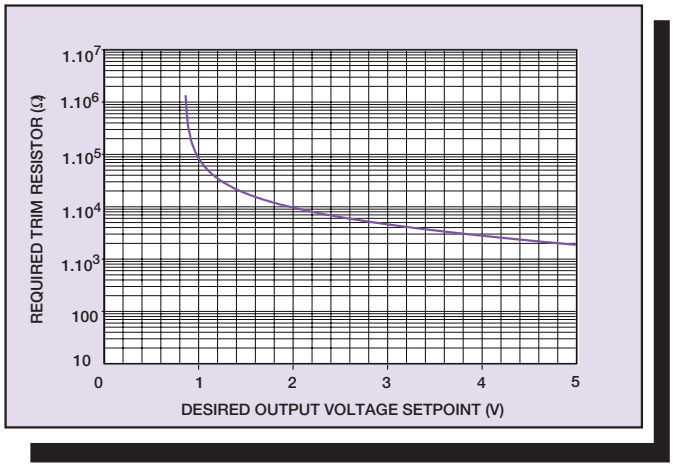


Figure 10 - Typical Trim Curves

The voltage trim equation with example is as follows:

Example:
Set Vt = 1.25V

Vt = 1.25V Vout = 2.5V Rs = 1kΩ

$$\text{Rt:} = \frac{\text{RS}\,(13.1\text{Vt} + \text{Vout} - 12.69)}{0.9\,\text{Rs} - \text{Vout}\,\text{Rs} - \text{Vout} + 12.69}$$

Rt = 0.72kΩ

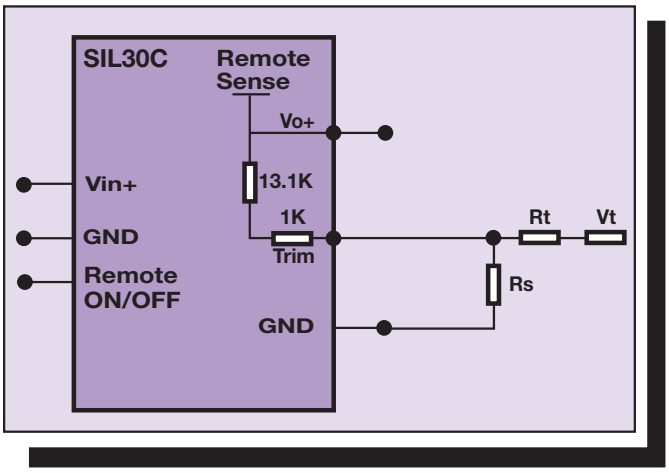


Figure 11 - Trim Output Voltage - with Voltage Source

7.4 Remote Sense Compensation
The remote sense compensation feature minimizes the effect of resistance in the distribution system and facilitates accurate voltage regulation at the load terminals or another selected point. The remote sense lines will carry very little current and hence do not require a large cross-sectional area. However, if the sense lines are routed on a PCB, they should be located close to a ground plane in order to minimize any noise coupled onto the lines that might impair control loop stability. A small 100nF ceramic capacitor can be connected at the point of load to decouple any noise on the sense wires. The module will compensate for a maximum drop of 400mV. Remember that when using remote sense compensation all the resistance, parasitic inductance and capacitance of the distribution system are incorporated into the feedback loop of the power module. This can have an effect on the modules compensation capabilities, affecting its stability and dynamic response.

7.5 Parallel Operation
Parallel operation of multiple converters is available since the SIL30C has a current sharing option. The converter will share to within ±10% of full load.

Note the remote sense lines of the parallel units must be connected at the same point for proper operation in addition to the current share pins being connected. Also, units are intended to be turned on/enabled at the same time. Warm plugging is not recommended.

7.6 Output Capacitance
The SIL series does not have output capacitors on the converter. Therefore, an external output capacitor is required for stable operation. Also, when powering loads with large dynamic current requirements, improved voltage regulation can be obtained by inserting capacitors as close as possible to the load. The most effective technique is to locate low ESR ceramic capacitors as close to the load as possible, using several capacitors to lower the overall ESR. These ceramic capacitors will handle the short duration high frequency components of the dynamic current requirement. In addition, higher values of electrolytic capacitors should be used to handle the mid-frequency components.

It is equally important to use good design practices when configuring the DC distribution system. Low resistance and low inductance PCB layout traces should be utilized, particularly in the high current output section. Remember that the capacitance of the distribution system and the associated ESR are within the feedback loop of the power module. This can have an effect on the modules compensation capabilities and its resultant stability and dynamic response performance. With large values of capacitance, the stability criteria

depend on the magnitude of the ESR with respect to the capacitance. Note that the maximum rated value of output capacitance varies between models and for each output voltage setpoint. The reader is directed to the relevant long form data sheet for details on the maximum allowable load capacitance for each model and setpoint. However, these values only guarantee start-up, not stability.

A stability vs Load Capacitance calculator, available on **www.artesyn.com/powerlab**, details how an external load capacitance influences the gain and phase margins of the SIL30C module.

Contact your local Artesyn Technologies representative if larger output capacitance values are required in the application.

7.7 Reflected Ripple Current and Output Ripple and Noise Measurement

The measurement set-up outlined in Figure 12 has been used for both input reflected/terminal ripple current and output voltage ripple and noise measurements on SIL series converters.

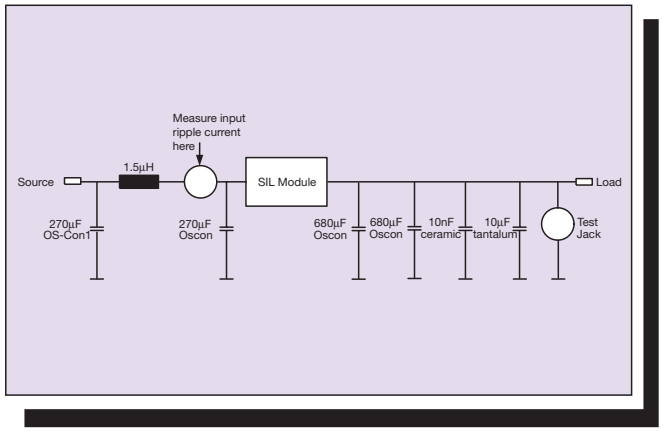


Figure 12 - Input Reflected Ripple/Capacitor Ripple Current and Output Voltage Ripple and Noise Measurement Set-Up

7.8 Input Ripple Current Capacitor Requirements

Care must be taken when selecting the external input capacitor. The equation below calculates the input ripple current for a particular model and output voltage setpoint. The selected input capacitor must be capable of supporting this ripple current. Figure 13 shows the variation of input ripple current with output current

$$I_{ripple} = \frac{I_{out}}{2}\sqrt{\frac{2D}{Efficiency}} \times \left(1 - \frac{2D}{Efficiency}\right) \quad \text{where } D = \frac{V_{out}}{V_{in}}$$

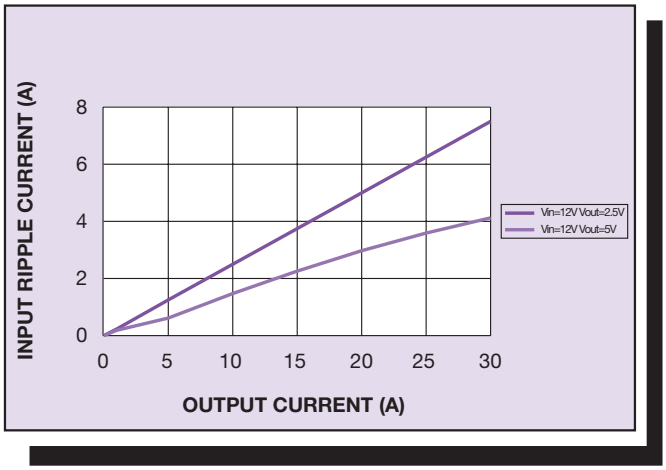


Figure 13 - Input Ripple Current with Output Current